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Creation of multi-layered canopy structures in young oak-dominated urban woodlands – The '*ecological approach*' revisited

Gustav Richnau[a], Björn Wiström[a], Anders Busse Nielsen[a,*], Magnus Löf[b]

[a] *Swedish University of Agricultural Sciences, Faculty of Landscape Planning, Horticulture and Agricultural Science, Department of Landscape Management, Design and Construction, Sweden*
[b] *Swedish University of Agricultural Sciences, Faculty of Forest Sciences, Southern Swedish Forest Research Centre, Sweden*

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ABSTRACT

We investigated the stand structure of ten young urban woodlands established in Southern Scandinavia during the 1970s and 1980s according to the *ecological approach*, which advocated the use of many different species of trees and shrubs to create complex canopy structures as soon as possible after establishment to promote recreation and biodiversity. Tree height and live crown depths were measured and analysed using a combination of quantitative and qualitative approaches to assess the forest structure in terms of canopy stratification. The results show that the current canopy structures could be classified into seven different two- and three-layered structural types which had evolved as a combination of differences in management frequency and the initial species composition. Two layered stands were characterized by lower management frequency compared to three layered stands and stands in transition to three layers. They were also established with a lower proportion of understory species and a higher proportion of shade tree species. The total number of species at the establishment did not influence how stands were categorized. The two main conclusions are that recurrent thinnings is a key factor for successful management of young, species rich forest plantations, and that species composition can increase the resilience towards management neglect. Instead of aiming at maximising total species number it is more reasonable to focus on a few key species in each layer. We conclude that three-layered canopy structures can be created already after twenty five years, which should encourage planners and practitioners to incorporate multilayered stands in future urban woodland creation.

Introduction

During the last decades, increasing the forest cover near cities has become a political priority in many European countries (Konijnendijk, 2000; Weber, 2000). Consequently the area of young woodlands, particularly oak-dominated, has increased significantly in and around towns and cities particularly in the forest poor North-Western parts of Europe (Gundersen et al., 2005; Nielsen and Jensen, 2007; Jensen and Skovsgaard, 2009). Due to the high pressure on forests in and near towns and cities, it is beneficial to take advantage of new forest plantations already during their young stages of development, both for attaining recreationally attractive environments and creating rich biodiversity habitats at an early age. Young forests are however often perceived as unattractive and unsuitable for recreation (Gundersen and Frivold, 2008; Jensen and Skovsgaard, 2009) as well as poor in biodiversity (Christensen and Emborg, 1996; Nilsson et al., 2001). This can be attributed to the lack of specific forest structural attributes, including horizontal and vertical canopy complexity (Niklasson and Nilsson, 2005; Nielsen and Jensen, 2007). The formation of stratified canopy structures is generally associated with the later phases of stand development while young forests have 'simple, top-loaded, single-layered canopies' (Franklin and Van Pelt, 2004). This progression is due to several co-interactive factors such as changes in light conditions due to small-scale gap formation and subsequent colonization of shade tolerant understory tree and shrub species.

Canopy stratification has enabled forest structure to be classified and conceptualised in different ways (Parker and Brown, 2000). It has for long been an interest to many disciplines in the context of management for timber production, wildlife as well as recreation. Stratification of canopies into overstory and understory layers are of ecological importance for flora and fauna, including various insects and birds (e.g. Ishii et al., 2004; Vance et al., 2007; Gunnarsson et al., 2009). Furthermore, forest preference studies have shown that stratified canopies can be a highly appreciated feature for forest recreation (Silvennoinen et al., 2001; Gundersen and Frivold, 2008). However, the number of strata per se should not be considered as a direct measure of how appealing a certain forest stand is

* Corresponding author. Tel.: +46 40415212.
E-mail address: Anders.Busse.Nielsen@slu.se (A.B. Nielsen).

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(Ribe, 1989; Heyman, 2011). Multi-layered forest stand types have been considered as among the most valuable types for integration of biological and recreational qualities, and thus a keystone stand type to be included in the urban woodland context (Gustavsson, 2004).

Departing from a landscape architecture tradition focusing on spatial architecture of the forest, Gustavsson (1986) and Gustavsson and Fransson (1991) developed a conceptual approach, which classified forest stands into different structural types based on the vertical and horizontal distribution of tree crowns and species. This framework allowed for a discussion of different strategies for woodland creation as an alternative to the prevailing use of even-aged monoculture plantations that was considered inappropriate for urban forestry objectives. The structural approach by Gustavsson was part of what has become known as the 'ecological approach to landscape design' (Thompson, 1998), which emerged primarily during the 1970s and found favour with practitioners and academics in many North European countries like Denmark, Germany, Holland, Sweden and the UK (Tregay and Gustavsson, 1983; Tregay, 1986; Forbes et al., 1997; Ruff, 2002). By drawing inspiration from natural and semi-natural temperate forest ecosystems, different tree and shrub species with varying life forms, shade tolerance, and successional strategies were mixed in the initial planting. It was argued that with proactive design and management, stratification of tree and shrub crowns into different canopy layers should be achievable already shortly after establishment (Tregay and Gustavsson, 1983; Tregay, 1986).

Many of the conceptual ideas of the *ecological approach* became integrated in the general landscape practice in Europe during the 1990s (Thompson, 1998). Current recommendations for woodland creation include the use of multiple species including both canopy trees and understory shrub species (e.g. Blakesley and Buckley, 2010). However, there is a lack of empirical studies on how forests established according to the *ecological approach* have developed and how management frequency and species composition influence canopy stratification. In this study, we reconstruct the management history and species mixtures at planting in ten forest stands established according to the *ecological approach* during the 1970s and 1980s as part of the rapid urban developments in southern Scandinavia. The objectives were to assess the different stand structure and canopy stratification that had developed as a result of (1) differences in management frequency, and (2) differences in species mixtures at planting.

Materials and methods

Study sites

The study was carried out in the Öresund region of Sweden and Denmark during 2008 and 2009 (Fig. 1). Four major forest establishment projects initiated during late 1970s and early 1980s that had clear references to the *ecological approach* were identified as case study areas. These were (1) the Alnarp Landscape Laboratory (A) a demonstration forest located adjacent to the campus of the Swedish University of Agricultural Sciences, (2) the Bulltofta Park (B) in Malmö established on a former airfield and today one of the largest and most visited recreational areas of the city, (3) the Filborna forest (F) in Helsingborg established to serve as a green corridor connecting the inner city parks with the recreation landscape on the urban fringe, and (4) the Ishøj Nature park (I), a young frequently visited recreational landscape south of Copenhagen.

All four study sites included a variety of forest stand types as well as semi-open and open areas. At each location, forest stands established with the aim of developing multi-layered canopies were identified. Among those, all stands where the species composition included *Quercus robur* L. in combination with one or several understory tree or shrub species were selected for inventory. The focus on *Quercus* was because this species has been favoured for afforestation, and has also increasingly been replacing conifers when long-established forests have been regenerated in Denmark and Southern Sweden (Jensen and Skovsgaard, 2009). The latter is especially the case in publicly owned forests close to cities (Gundersen et al., 2005).

Reconstruction of species mixture and management history

Information about year of establishment and the species mixtures at planting were acquired from consultation of reports and archives in the authorities owning the individual woodlands. In total ten mixed stands with *Quercus robur* were identified, having varying stand sizes and original species compositions (Table 1). Henceforth the stands are referred to as A1, A2, B1, B2, F1, F2, F3, I1, I2 and I3. Validity of identified species mixture was controlled (and in two cases corrected; B2, I1) through consultation of present and former managers and field visits.

For all stands descriptions of management strategy and long-term aim for stand development had been established at the time of afforestation. For the stands in Alnarp Landscape Laboratory and Bulltofta these have also been published (Qvarnström and Rosenqvist, 1980; Nielsen et al., 2005). However, information about conducted operational management since the stands were established had not been added to the management plans. Thus for all stands the timing and intensity of thinning and other operational management actions had to be reconstructed through interviews with present and former managers, together with whom we also searched in archives. The results of this reconstruction is summarised in Appendix A, and revealed that some of the stands had been thinned 1–2 times (B1, B2, F1, F2, F3, I2) indicating a neglected management, while other stands had been thinned 3–5 times (Table 1).

Mixed-method design

The oldest and most widely used method to study canopy stratification is the use of profile diagrams (Baker and Wilson, 2000). Profile diagrams, often combined with crown projection diagrams, have gained interest during the last century, especially where mixed-forest management has been practiced, indicating that the more irregular the stand structures are the greater need for integrative and visual tools (e.g. Nielsen and Nielsen, 2005; Nielsen, 2006). Identification of canopy layers from profile diagrams is however visually and qualitatively assessed, and has been criticised as a subjective and non-reproducible method (Parker and Brown, 2000). This has resulted in the development of various mathematical canopy stratification models that allow for a more objective comparison (Latham et al., 1998; Baker and Wilson, 2000; Everett et al., 2008). In this study we combine the two methods in order to develop a more complete and nuanced portrait of the studied stands.

Data collection

Data collection was carried out in study plots in all stands. The number of plots per stand was determined according to the size of the stand where stand area <0.75 ha = 2 plots, 0.75–1.5 ha = 3 plots and 1.5–3 ha = 4 plots. We chose to locate the plots subjectively to ensure that structural variations within the stands were represented. Plot size was set to 15 m × 15 m except for one of the A2 plots where a plot size of 10 m × 10 m was used to avoid